(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 375 854 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
12.10.2011 Bulletin 2011/41

(21) Application number: **11160239.7**

(22) Date of filing: **29.03.2011**

(51) Int Cl.:
H05B 1/02 (2006.01) ***H05B 3/82*** (2006.01)
F01N 3/20 (2006.01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **06.04.2010 EP 10159125**

(71) Applicant: **Inergy Automotive Systems Research (Société Anonyme)**
1120 Bruxelles (BE)

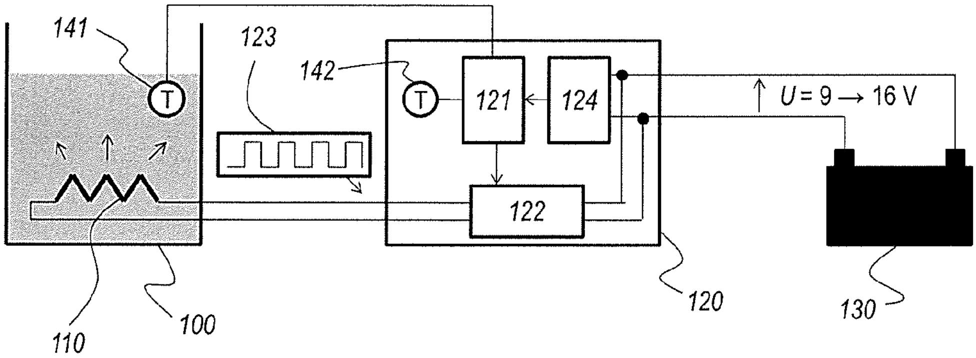
(72) Inventors:
- **Etorre, Laurent**
  1030, SCHAERBEEK (BE)
- **Barzic, Florent**
  80637, MUNICH (DE)
- **Lavenier, François-Régis**
  1090, JETTE (BE)
- **Naydenov, Volodia**
  1348, LOUVAIN-LA-NEUVE (BE)
- **Zeller, Guillaume**
  1040, BRUSSELS (BE)
- **Garcia-Lorenzana, Ignacio**
  60325, FRANKFURT AM MAIN (DE)

(74) Representative: **Vande Gucht, Anne et al**
Solvay S.A.
Département de la Propriété Industrielle
Rue de Ransbeek, 310
1120 Bruxelles (BE)

(54) **Heater for a vehicular fluid tank, motor vehicle comprising same, and method for heating a vehicular fluid tank**

(57) A heating system for a vehicular fluid tank (100), said heating system comprising at least one resistive element (110) and a control unit (120) adapted to direct an electric current through said at least one resistive element (110), wherein said control unit (120) is adapted to vary said current according to a pulse width modulation scheme.

Figure 1



EP 2 375 854 A1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention pertains to a heating system for a vehicular fluid tank, said heating system comprising at least one resistive element and a control unit adapted to direct an electric current through said at least one resistive element. The present invention also pertains to a motor vehicle comprising such a heating system. The present invention also pertains to a method for heating a vehicular fluid tank.

[0002] Heating systems for vehicular fluid tanks, in particular for tanks intended to hold liquids which can freeze at normal winter temperatures, such as ammonia precursor solutions used in selective catalytic reduction reactions (SCR) to treat exhaust gas from internal combustion engines, are known in the art. A commonly used type of precursor solution is a eutectic liquid mixture of water and urea, which is commercially available under the trademark AdBlue. This solution is known to freeze at temperatures below approximately -11 °C, a condition which regularly occurs during winter time in many areas of the world. Hence, it is necessary under these conditions to thaw a quantity of the stored solution before the reduction of the NOx compounds in the exhaust gas can start taking place.

[0003] Patent application WO 2008/138960 A1 in the name of applicant describes a urea tank and base plate with an integrated heating element. The integrated heating element comprises at least one flexible heating part. Preferably, the flexible part is a flexible heater, that is to say that it comprises at least one resistive track inserted between two flexible films or affixed to a flexible film.

[0004] In the heating systems described above, it is important to avoid overheating of the ammonia precursor solution, which could lead to unpleasant odors and even to undesirable alterations of the properties of the solution. The prior-art solution to this problem is to use heating elements with a resistance that has a positive temperature coefficient (PTC), thus providing a certain amount of self-regulation. However, when the PTC is warm, less heating power is available. Besides, since the current consumption varies with temperature, a diagnosis of the heater based on the plausibility of the current consumption is difficult.

[0005] In typical automotive situations, the power supply voltage can range between 9 and 16 Volt, depending on the overall instantaneous load on the electrical system. The supply voltage fluctuates as various electrical functions switch on and off, as a result of actions by the vehicle operator or instructions from the vehicle electronics. Typically, these electrical functions are a mix of high-consumption functions such as an air conditioning unit and a rear window defroster, and low-consumption unit such as various electronic circuits and indicators. These functions may cycle through on and off status at very diverse timescales. As a result, the amount of heat dissipated by the resistive element will also fluctuate, making it difficult to control the precise conditions under which the content of the vehicular fluid tank will be thawed and/or heated.

[0006] The controllability of the heating conditions is a serious concern for SCR systems, because vehicle manufacturers want to ensure a sufficiently rapid thawing process to comply with applicable emission standards, in particular with respect to NOx emissions, while avoiding overheating of the ammonia precursor solution. It is a further concern to avoid overheating of the heating system itself, including for example the control unit, the fluid container, the wiring and the resistive elements.

[0007] It is an object of the present invention to provide a heating system of the kind described above that meets the above concerns.

[0008] According to an aspect of the invention, there is thus provided a heating system as described, wherein the control unit is adapted to vary said current according to a pulse width modulation scheme.

[0009] The invention is based on the insight that by varying the duty cycle of the pulse width modulated current, the amount of heat dissipated by the resistive element varies in the same degree.

[0010] Hence, the heating system can advantageously be dimensioned to operate according to a desired characteristic at the lowest supply voltage that can normally be expected, and the duty cycle of the pulse width modulated current can then be modulated to compensate when the actual supply voltage is higher than this minimum.

[0011] The use of pulse width modulation to control a heater is known in the art. US patent application 2004/0170212 A1 discloses the use of pulse width modulation to control the average effective current directed through a resistance heater. The heater disclosed therein is intended for heating a sensor and does not have the required characteristics for use with a vehicular fluid tank.

[0012] It is a further object of embodiments of the present invention to allow for a staged thawing process, in which a first stage operates at a higher level of heat dissipation, as required to rapidly thaw a sufficient quantity of solution to allow a pump to start operating, and a second stage operates at a lower level of heat dissipation, to allow a gradual thawing of the remainder of the tank contents.

[0013] In an embodiment of the heating system of the present invention, the pulse width modulation scheme is applied so that at least two distinct heating power levels can be obtained.

[0014] This embodiment has the advantage of allowing a staged thawing process. The respective desired characteristics are obtained by applying a further modification to the duty cycle.

[0015] In an embodiment of the heating system of the present invention, the control unit is adapted to determine the duty cycle in inverse proportion to the square a smoothened measurement of the supply voltage.

[0016] Use of a smoothened measurement has the advantage that high-frequency fluctuations of the supply voltage are ignored. This can be done without negatively impacting the operation of the heating system, because the thermal inertia of the resistive element and its surroundings will normally be sufficiently large to make very fine-grained modulation thermally undetectable.

[0017] In an embodiment, the heating system further comprises a temperature sensor operatively coupled to said control unit, wherein said control unit is adapted to modify a duty cycle of said current in response to a temperature reading received from said temperature sensor.

[0018] This embodiment has the advantage of being able to provide an additional protection against overheating of selected parts of the vehicular tank system. In a particular embodiment, the temperature sensor is placed in or near the control unit. This embodiment has the advantage of protecting the control unit, which may be implemented with temperature-sensitive electronics. In another particular embodiment, the temperature sensor is placed near the resistive element. This embodiment has the advantage of providing a real feedback loop, such that the system can operate like a thermostat in addition to the control features described above.

[0019] According to an aspect of the invention, there is provided a motor vehicle comprising a fluid tank equipped with the heating system of the invention.

[0020] According to another aspect of the invention, there is provided a method for heating a vehicular fluid tank with at least one resistive element receiving an electric current from a power supply under the control of a control unit (120), the method comprising varying said current according to a pulse width modulation scheme.

[0021] In an embodiment of the method of the present invention, the pulse width modulation scheme is applied in such a way that at least two distinct heating power levels can be obtained.

[0022] In an embodiment, the method of the present invention further comprises measuring a voltage of said power supply, smoothening said supply voltage, and determining a duty cycle for said pulse width modulation in inverse proportion to the square of said smoothened supply voltage.

[0023] In an embodiment, the method of the present invention further comprises measuring a temperature, and modifying a duty cycle of said current in response to said temperature. In a particular embodiment, said temperature is measured in or near said control unit (120). In a particular embodiment, said temperature is measured near said resistive element (110).

[0024] These and other aspects of the invention will be better understood by reference to the following figures, in which:

Figure 1 is a schematic representation of the heating system of the present invention;
Figure 2 is a diagram of the relative pulse width in function of the supply voltage in a heating system according to the present invention; and
Figure 3 is a flow chart of an embodiment of the method according to the present invention.

[0025] The embodiment schematically depicted in Figure 1 comprises a resistive element **110** inside a vehicular fluid tank **100,** in particular tank for holding a urea solution, whereby the resistive element **110** is used to heat the content of the tank **100.** In particular embodiments of the system of the present invention, resistive elements may also or instead be arranged outside and near the tank, or at accessories of the tank which require expedited thawing of the surrounding solution, such as a urea solution pump.

[0026] The resistive element **110** receives a current from a control unit **120,** which draws its energy from a power supply, here depicted as a battery **130.** The skilled person shall understand that although only a battery **130** is shown, other power supply elements such as an alternator may be present in addition to or as an alternative to the battery **130.**

[0027] The skilled person will also appreciate that wherever in this description the control unit **120** is described as delivering, directing, or controlling a current, this action may in fact be accomplished by acting accordingly on the voltage of the corresponding electrical signal, the two variables being intrinsically linked by the overall resistance of the circuit through which the electrical energy is led.

[0028] Control unit **120** is adapted to convert the power supply voltage provided by battery **130,** which may fluctuate between approximately 9 V and approximately 16 V, into a pulse width modulated electrical signal, schematically illustrated as block wave **123.** The energy in this signal is converted to heat by the resistive element **110.**

[0029] To this end, the control unit **120** comprises a duty cycle calculating agent **121** and a switching agent **122.**

[0030] The duty cycle calculating agent **121** combines all relevant information to determine the desired duty cycle according to the present inventive concept. Thus, the duty cycle calculating agent **121** is adapted to determine the required duty cycle for a desired level of heat dissipation, taking into account the instantaneous supply voltage level delivered by the battery **130,** as described in more detail with reference to Figure 2 below. Preferably, the duty cycle calculating agent **121** is adapted to determine the respective required duty cycles for a first and a second desired level of heat dissipation, taking into account the instantaneous supply voltage level. The duty cycle calculating agent **121** measures the supply voltage directly, or indirectly after the operation of smoothener **124,** which is intended to remove high-frequency fluctuations from the measured supply voltage measurement. The smoothener **124** may be implemented as a usual low-pass filter.

[0031] The control unit **120,** and more particularly the duty cycle calculating agent **121,** is operatively coupled to a first temperature sensor **141** arranged near the resistive element **110,** preferably in the tank **100,** and/or a second temperature sensor **142** arranged in or near said control unit **120.** The duty cycle calculating agent **121** can take temperature readings from these temperature sensors **141, 142** into account in the determination of the duty cycle, in order to meet additional objectives, such as avoiding unnecessary heating of the tank 100 when the content is not frozen, avoiding overheating of the content of the tank 100, and avoiding overheating of the control unit **120,** the components of which may be temperature-sensitive.

[0032] The switching agent **122,** operatively coupled to the duty cycle calculating agent **121,** is adapted to perform the actual pulse width modulation according to the duty cycle determined by the duty cycle calculating agent **121,** thus transforming the voltage supplied by the battery **130** into the desired voltage wave **123.**

[0033] The duty cycle calculating agent **121** and the switching agent **122** may be implemented, separately or together, using any of the well known technologies for electronic control circuitry, including for example appropriately programmed processors or microcontrollers, appropriately configured programmable logic including field-programmable gate arrays (FGPAs), dedicated integrated circuits (ASICs), and discrete electronic circuits.

[0034] Figure 2 represents the relative pulse width in function of the supply voltage in a heating system according to an embodiment of the present invention. For illustrative purposes, it is assumed that the heating system is adapted to operate at a first heating power level of P_1 = 100 W and a second heating power level of P_2 = 50 W. The heating system is designed to provide these power levels at a supply voltage level of U_{min} = 8 V, which corresponds to slightly less than the lowest normally expected supply voltage in a typical automotive system. As $P_2 = U_{\mathrm{min}}^2/R$ for a duty cycle of 100%, i.e. for a heater that is always on, we find that the resistive element has to have a resistance of 0,64 Ω

[0035] In order to maintain a first heat dissipation level of 100 W for levels of the supply voltage above the minimum level mentioned above, the duty cycle of the pulse width modulated heating current is reduced. Thus, as a twofold increase in the supply voltage, i.e. a supply voltage of 16 V, would result in a fourfold increase in heat dissipation under otherwise identical conditions, the corresponding duty cycle has to be set to 25% in order to maintain a 100 W heat dissipation level. The same calculation applies to any intermediate value of the supply voltage, thus leading to the uppermost curve (with data points shown as solid bullets) in the diagram of Figure 2, in which the resulting duty cycle clearly displays a $1/U^2$ proportionality.

[0036] In order to obtain a second heat dissipation level of 50 W at the minimum supply voltage level U_{min} mentioned above, the duty cycle of the pulse width modulated heating current is set to 50% at this voltage. To maintain this level of heat dissipation for levels of the supply voltage above the minimum level, the duty cycle is further reduced. Again, as a twofold increase in the supply voltage, i.e. a supply voltage of 16 V, would result in a fourfold increase in heat dissipation under otherwise identical conditions, the corresponding duty cycle has to be set to 12.5% in order to maintain a 50 W heat dissipation level. The same calculation applies to any intermediate value of the supply voltage, thus leading to the lowermost curve (with data points shown as hollow bullets) in the diagram of Figure 2, in which the resulting duty cycle again clearly displays a $1/U^2$ proportionality.

[0037] In Figure 2, the hashed region representing supply voltage levels between 0 V and 8 V is an anomalous region. It is not possible to determine a duty cycle value between 0% and 100% which would lead to the desired heat dissipation of 100 W if the resistance of the heating element is chosen as indicated above. Using duty cycle values above 50%, it is in principle possible to provide a heating level of 50 W as long as the supply voltage is greater than or equal to

$$U_{50\mathrm{W}} = \sqrt{(100\% \times 50\ \mathrm{W} \times 0{,}64\ \Omega)} = 5{,}66\ \mathrm{V}.$$

[0038] Figure 3 represents a flow chart of an embodiment of the method of the present invention.

[0039] In step **310,** a desired heat level is selected from at least a first and a second desired level of heat dissipation. This may happen according to a predetermined time-schedule, for instance in order to apply a higher heat dissipation level during a predetermined time T_1 immediately after the engine start, and a lower heat dissipation level after the expiry of time T_1. In step **320,** the instantaneous power supply voltage is measured. The supply voltage is optionally smoothened at step **330.**

[0040] The order of steps **320** and **330** may vary between embodiments. The supply voltage may be measured as it is, whereupon a numerical smoothening algorithm, such as a time averaging algorithm, is applied to the measurement values. Alternatively, the supply voltage may be passed through a low-pass filter or other electronic smoothening means, whereupon the smoothened signal is measured for further use by the control unit. Measurement and smoothening may also be combined, for instance by using a low-frequency sample-and-hold measurement method.

[0041] Optionally, one or more temperature values are obtained by measurement, preferably by temperature sensors positioned as described above for sensors **140** and **141** of Figure 1.

[0042] Finally, in step **350,** all the relevant information is combined to determine the desired duty cycle according to the present inventive concept. Thus, the control unit **120** determines the required duty cycle for one of at least a first and a second desired level of heat dissipation, taking into account the instantaneous supply voltage level delivered by the battery **130,** as described in more detail with reference to Figure 2 above. Temperature measurements, if available, are taken into account so as to further reduce the duty cycle (or even shut down the heating system completely, which corresponds to a duty cycle of 0%), for instance when the measurement of the temperature indicates a risk of overheating of the tank contents and/or the control unit.

[0043] Although the method of the present invention has been described and illustrated as a series of consecutive steps, the skilled person will appreciate that the order of these steps is generally not material to the invention.

[0044] Although the invention has been described herein with reference to certain exemplary embodiments, the skilled person will understand that these embodiments serve to illustrate and not to limit the invention, the full scope of which is determined by the enclosed claims.

Claims

1. A heating system for a vehicular fluid tank (100), said heating system comprising at least one resistive element (110) and a control unit (120) adapted to direct an electric current through said at least one resistive element (110), **characterized in that** said control unit (120) is adapted to vary said current according to a pulse width modulation scheme.

2. The heating system of claim 1, wherein the pulse width modulation scheme is applied so that at least two distinct heating power levels can be obtained.

3. The heating system of claim 1 or claim 2, wherein the control unit (120) is adapted to determine a duty cycle of said current in inverse proportion to the square of a smoothened measurement of the supply voltage.

4. The heating system of any of the preceding claims, further comprising a temperature sensor (141, 142) operatively coupled to said control unit (120), wherein said control unit (120) is adapted to modify a duty cycle of said current in response to a temperature reading received from said temperature sensor (141, 142).

5. The heating system of claim 4, wherein said temperature sensor (142) is placed in or near said control unit (120).

6. The heating system of claim 4, wherein said temperature sensor (141) is placed near said resistive element (110).

7. A motor vehicle comprising a fluid tank equipped with the heating system of any of the preceding claims.

8. The motor vehicle of claim 7, wherein said fluid tank (100) is a tank for storing an additive to be used in a selective catalytic reduction reaction.

9. A method for heating a vehicular fluid tank (100) with at least one resistive element (110) receiving an electric current from a power supply under the control of a control unit (120), **characterized in that** said method comprises varying said current according to a pulse width modulation scheme.

10. The method of claim 9, wherein said pulse width modulation scheme is applied in such a way that at least two distinct heating power levels can be obtained.

11. The method of claim 9 of claim 10, further comprising measuring a voltage of said power supply, smoothening said measured supply voltage, and determining a duty cycle for said pulse width modulation in inverse proportion to the square of said smoothened measured supply voltage.

12. The method of any of claims 9-11, further comprising measuring a temperature, and modifying a duty cycle of said current in response to said temperature.

13. The method of claim 12, wherein said temperature is measured in or near said control unit (120).

14. The method of claim 12, wherein said temperature is measured near said resistive element (110).

Figure 1

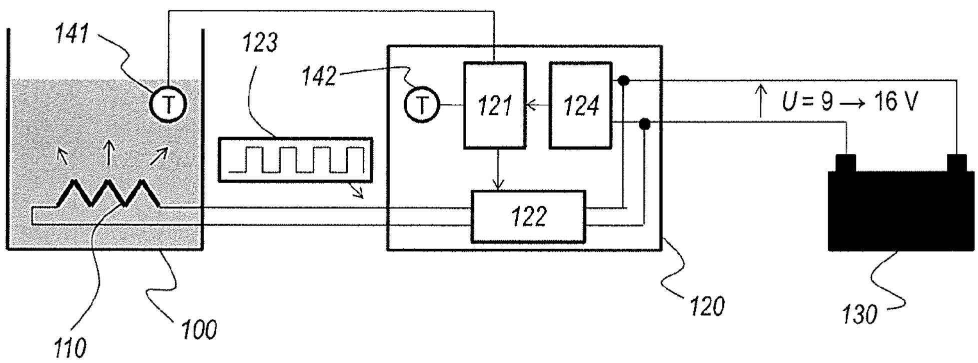


Figure 2

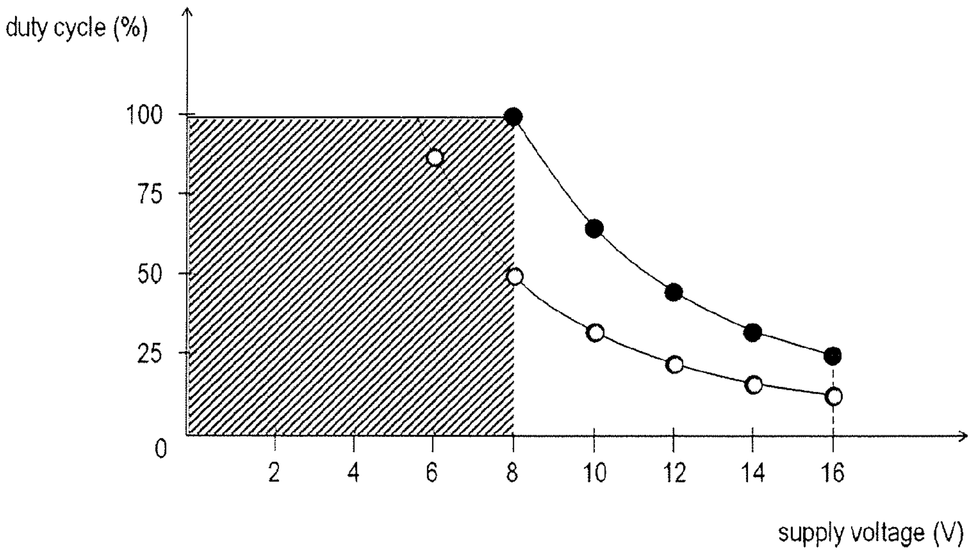
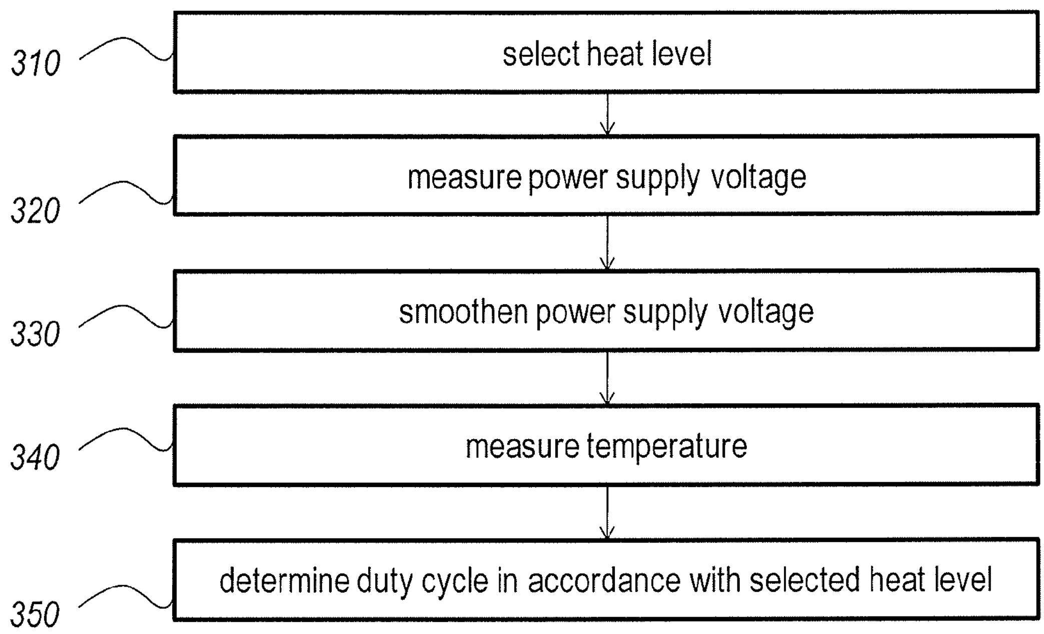


Figure 3


310
select heat level
320
measure power supply voltage
330
smoothen power supply voltage
340
measure temperature
350
determine duty cycle in accordance with selected heat level

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 11 16 0239

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 505 292 A2 (ELTEK SPA [IT]) 9 February 2005 (2005-02-09) * paragraph [0075]; figure 1 *	1,7,9, 10,12	INV. H05B1/02 H05B3/82 F01N3/20
X	US 4 504 732 A (BUBE CARSTEN [DE] ET AL) 12 March 1985 (1985-03-12) * column 2, line 36 - line 48; figures 1,2,6 *	1,7,9	
X	WO 86/02227 A1 (AMERICAN HOSPITAL SUPPLY CORP [US]) 10 April 1986 (1986-04-10) * page 17, line 12 - line 21; figure 1 *	1	
X	US 6 080 971 A (SEITZ DAVID [US] ET AL) 27 June 2000 (2000-06-27) * column 9, line 39 - column 10, line 26; figures 1,2 *	1	
X	AU 661 557 B2 (IMI SANTON LTD) 27 July 1995 (1995-07-27) * page 3, line 23 - line 32; figures 1,2 *	1	TECHNICAL FIELDS SEARCHED (IPC)
X	WO 91/17640 A1 (SEITZ DAVID E [US]) 14 November 1991 (1991-11-14) * page 19; figures 1,8,9 *	1	H05B F01N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	12 July 2011	Gea Haupt, Martin

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 16 0239

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

12-07-2011

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1505292	A2	09-02-2005	EP	2075452	A2	01-07-2009
			ES	2325436	T3	04-09-2009
			ES	2361968	T3	24-06-2011
US 4504732	A	12-03-1985	DE	2726458	A1	04-01-1979
			FR	2394223	A1	05-01-1979
			GB	1596717	A	26-08-1981
			JP	63164569	U	26-10-1988
			JP	63045993	U	28-03-1988
			JP	54005238	A	16-01-1979
			US	4348583	A	07-09-1982
WO 8602227	A1	10-04-1986	CA	1261173	A1	26-09-1989
			EP	0197085	A1	15-10-1986
			JP	62500330	T	05-02-1987
			US	4625096	A	25-11-1986
US 6080971	A	27-06-2000	NONE			
AU 661557	B2	27-07-1995	AU	3398493	A	15-09-1994
			NL	9300425	A	03-10-1994
WO 9117640	A1	14-11-1991	AU	670397	B2	11-07-1996
			AU	7740794	A	05-01-1995
			AU	651980	B2	11-08-1994
			AU	7987791	A	27-11-1991
			CA	2082521	A1	11-11-1991
			DE	69122245	D1	24-10-1996
			DE	69122245	T2	07-05-1997
			EP	0527933	A1	24-02-1993
			US	7616873	B1	10-11-2009
			US	5216743	A	01-06-1993

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2008138960 A1 **[0003]**
- US 20040170212 A1 **[0011]**